INSTRUMENTATION OF THE HADRON BEAMS IN THE NEUTRINO AREA

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April 28, 1971

The instrumentation needed to implement the tuning and control of the neutrino area hadron beams specified in TM-285 are described. For convenience we choose to consider the hadron beam complex as composed of three separate units. The first, Beam N7, is the transport section from the end of the hadron shield to the hadron beam target approximately 200 feet downstream. The second, Beam N3, transports particles from this target to the ANL 30" bubble chamber. The third, Beam N5, has a target and front end in common with Beam N3 but diverges from it near the first focus and continues to the NAL 15 foot bubble chamber.

The initial goal for each of these beams is to produce a controlled number of particles to the bubble chamber of well defined purity. A possible later development is the correlation of particle mass and trajectory position in the bubble chamber on a particle by particle basis. For each of these three beams we first state what control functions are needed to meet these ends and then how we believe they should be accomplished.

We expect a control loop will be required to keep the beam images on the appropriate slits. This we will accomplish with a vernier magnet upstream of the slit and a proportional wire chamber (PWC) at the slit whose output is monitored by the beam control computer and an appropriate correction signal sent to the vernier magnet. This triplet of devices, vernier, proportional wire chamber and slit will be one of our basic instrumentation packages.

INSTRUMENTS

We describe the individual instruments needed for these beams.

<u>Collimator (C)</u> These will be used to control intensities and should have jaws which are movable in either the vertical or horizontal plane but not both; i.e., in a given location we never collimate simultaneously in both planes. A length of ten feet would be adequate. This length of iron insures that muons near the beam momentum passing through the jaws will lose sufficient energy to place them outside of the beam acceptance. It is desirable to be able to control the aperture remotely.

<u>SWIC</u> This is a segmented wire ionization chamber[1] and is used to determine image profiles where rates greater than

[1] F. Hornstra and J. R. Simanton, Nuclear Instruments and Methods, <u>77</u>, 303 (1969).

10^6 particles per second are encountered. Because of the short spill nature of this beam ($\sim 10^{-4}$ sec.) intensities greater than 10^3/pulse but less than 10^6/pulse may require redesign of standard instrumentation.

Wire Chamber (PWC) Here we refer to a high resolution wire proportional chamber described in FN-222. They will be used to determine image profiles where rates are 10^6 particles per second or less. Coincidences may be made between two such devices, one in the horizontal and one in the vertical plane, to give a two dimensional beam distribution. More often just a profile projection in either the horizontal or vertical plane will suffice.

Vernier Magnets (V) These will be used to steer the beam. They are described in EN-7027 and will deflect a 500 GeV/c particle by 0.18 mr. When possible a horizontal bending magnet will also be used as a vernier magnet. We now consider each of the three beams.

BEAM N7

Particles entering this beam from the neutrino decay tunnel are nearly parallel and will be focused on a hadron production target as shown in Fig. 1. We must be able to control the number of interactions in our target over a very wide range of incident beam intensities from the target box. This allows the bubble chambers to operate over the widest possible targeting conditions in the box. Slits controlling the horizontal and vertical apertures will be located as indicated in Fig. 1 and Table 1. The apertures of these slits should be controllable remotely from the beam control center. Intensities transmitted to the bubble chamber will also be controlled by the target thickness, therefore we should have the ability to change the target length and material easily and quickly. Profile indicators, in this case both a SWIC and a proportional wire chamber, would be located just upstream of the hadron target and would be needed in both the horizontal and vertical planes. To keep the beam centered on the target a vertical vernier magnet is located just before the last two quadrupole magnets. The last bending magnet also serves as a horizontal vernier. These two verniers should form a closed loop, either through the control computer or hard wired, to keep the beam image centered on the target. A three scintillator telescope viewing the target at 90° monitors the interaction rate in the target. A detector should also be placed at the exit of the neutrino shield to monitor the number of particles entering the Beam N7 channel. This detector could be a scintillator capable of operating in either a pulse mode counting individual particles or in an integrating mode for high flux rates. A removable plastic scintillation counter will also be placed just before the target to provide a fast trigger for low beam intensity operation. Table 2 gives a complete listing with position of each of the beam components for this beam.

Both Beam N3 and N5 use the target at the end of Beam N7 as their source.

BEAM N3

Beam N3 has its acceptance defined by horizontal and vertical collimators near the first quadrupole doublet in Enclosure 101. These are indicated in Fig. 2 and Table 3. A vertical vernier magnet at the end of this enclosure insures that the beam is properly steered onto the vertical focus in Enclosure 103. A collimator at the horizontal focus, F_{1H}, defines the momentum bite. The bending magnet which separates Beam N3 from Beam N5 is also used to steer each beam onto the next enclosure. Both a horizontal and a vertical profile monitor (PWC) will be needed just before the first momentum slit to provide a two dimensional profile at this point. A second vertical profile monitor will be needed just before the vertical focus to insure that the beam is centered on the collimator. A collimator at the vertical focus redefines the target's vertical extent. Because of the great distance between Enclosures 101 and 105, a vertical vernier magnet is required at the end of Enclosure 103.

Vertical and horizontal vernier magnets in Enclosure 105 provide a means for steering onto F_{2V} and F_{2H}.

Between Enclosure 105 and Enclosure 108 will be a pair of differential threshold Cerenkov counters which could be used in conjunction with wire proportional chambers before the bubble chamber to tag the mass and position of the entering particles. Appendix A describes these counters. Enclosure 108 contains a PWC and collimator acting in the vertical plane. The equivalent instrumentation in the horizontal plane is contained in Enclosure 110. Two additional pairs of proportional wire chambers could be put in after the last bending magnet and just before the bubble chamber. These would be the wire chambers whose output is recorded on magnetic tape with the Cerenkov counter information and is capable of being correlated with the tracks in the chamber to provide mass and incident angle tagging. Located strategically throughout the beam are scintillation counters which will provide fast coincidence signals for beam diagnostics. Table 4 gives the detailed positions of the components of this beam. Also indicated in Table 4 is a position for a vertical fast kicker magnet which we would use to deflect the beam onto a vertical slit after the desired number of tracks have traversed the beam. The magnet would need to produce an integral field of one kilogauss-meter within 1 μsec of being triggered.

BEAM N5

Beam N5 uses the same instrumentation as Beam N3 up through the bending magnets which separate them. Immediately following these bending magnets is a vertical PWC followed by a vertical collimator to define the target image. The PWC insures that the beam is centered on the collimator and checks for any image of extraneous material around the target. The final item in Enclosure 103 is a vertical vernier dipole. All three of these may be shared with Beam N3. The bending magnet dividing Beams N3 and N5 and the vertical vernier dipole are used to steer the beam onto Enclosure 105.

The bending magnets of Enclosure 105 are used as the horizontal vernier to steer the beam onto the second momentum slit in Enclosure 106. After the last quadrupole in Enclosure 105 is a vertical vernier dipole to steer the beam onto the vertical collimator in Enclosure 107. At the end of Enclosure 105 is the best location for a vertical kicker dipole magnet (K_V) which would be used to dump the beam onto the vertical collimator in Enclosure 107 when a preset number of particles have passed through a scintillation counter S_k just in front of the kicker. Again 1 kilogauss-meter within 1 μsec of being triggered would be sufficient.

Immediately after the field lens quadrupole in Enclosure 106 will be a horizontal profile monitor (PWC) to check on the effectiveness of the previous collimator and to see that the beam is centered on the following collimator. This second momentum collimator could be used to define the beam momentum somewhat more accurately than the first alone.

Enclosure 107 again contains the doublet of PWC and collimator - here acting in the vertical plane.

The bending magnets of Enclosure 109 are used as a horizontal vernier to steer the beam onto the clean-up collimator in Enclosure 111. At the end of Enclosure 109 is a vertical vernier dipole to steer the beam onto the collimator in Enclosure 111.

Enclosure 111 contains horizontal and vertical profile monitors (PWC), followed by horizontal and vertical collimators.

Enclosure 113 contains a parallel section of the beam where we may put a DISC Cerenkov counter if that seems justified by early work in the N3 beam.

Finally in Enclosure 115 are horizontal and vertical vernier dipoles to steer the beam into the bubble chamber. These could be followed by horizontal and vertical proportional chambers which, in combination with horizontal and vertical proportional chambers near the bubble chamber, would be used to tag both the incident direction and entrance position of each particle as it enters the chamber. This could be correlated with the signal from the Cerenkov counter to identify each particle's mass. All of this information could be recorded on magnetic tape for each particle entering the bubble chamber.

PRIORITIES

What has been described is a set of instrumentation to tune, control and monitor these beams as well as provide mass tagging of tracks at the entrance of the bubble chamber. This program will require a substantial allocation of manpower and money and must be considered a developmental effort which will require an extended period of time to bring to full fruition. To insure that an increasing amount of physics can be accomplished at any given time we must specify a set of instrumentation priorities. We consider here only the beam to the ANL 30 inch bubble chamber.

First Priority A controlled beam to the bubble chamber of known purity.

1. Beam N7 and its controls operational and providing particles on the hadron target.

2. Beam N3 operational with necessary controls to stabilize images on slits.

3. The Cerenkov counters operational to provide beam purity information.

4. Scintillators ahead of the bubble chamber.

5. A fast kicker magnet to limit the number of tracks in the bubble chamber.

<u>Second Priority</u> Incident particle tagging.

1. Wire proportional chambers immediately before the bubble chamber and correlated with chambers at E 114.

2. Data collection system to record on a particle by particle basis the position of the incident particles at the bubble chamber and several hundred feet upstream and the response of the Cerenkov counters. Magnetic tape output will be correlated with the picture number.

3. A proportional chamber at the momentum slit to tag the incident momentum when the beam optics are set to accept a wide momentum bite.

TABLE 1 Beam N7 Instrumentation

Location	Device	Purpose
Exit of neutrino shield	Scintillator to cover hole in shield. Must have large dynamic range.	Monitor beam from neutrino decay tunnel.
After center element of triplet	Horizontal collimator	Control horizontal acceptance
After horizontal collimator	Vertical collimator	Control vertical acceptance
Before last two quadrupoles	Vertical vernier	Steer beam onto target
Last bending magnet	Last bending magnet	Magnet will also act as vernier to keep beam on target.
Before hadron target	Profile monitors in both planes. Both wire chambers and SWIC. Plastic scintillator	Monitor beam profile, intensity and position at target.
Beside hadron target	Three scintillator telescope mounted at 90° to target axis.	Monitor interaction rate in target.

Closed Control Loops

1. Vertical vernier and vertical profile monitors at target.

2. Horizontal vernier (last bending magnet) and horizontal profile monitor at target.

TM-298
2254.000

MAGNET COORDINATE CODE

Table 2

MOMENTUM	500.00000
TARGET Z	3478.99996
X	-0.67000
ANGLE	-0.90000

'BEAM N7 MARCH 20, 1971

48

4816

ENCL. 100

	ELEMENT		LENGTH	FIELD	BEND	CURRENT	POWER	Z	X	ANGLE	
1	DRIFT		0.000					3479.0000	-0.6700	-0.900	NEUTRINO TARGET
2	DRIFT		1337.000					4147.4997	-1.2716	-0.900	DECAY TUNNEL
3	DRIFT		2.000					4815.9994	-1.8733	-0.900	END OF SHIELD
4	DRIFT		0.000					4815.9994	-1.8733	-0.900	SCINTILLATOR
5	DRIFT		43.000					4837.4994	-1.8926	-0.900	
6	QUAD	3Q52	4.330	-4.8100		-3506.97	32.12	4861.1644	-1.9139	-0.900	
7	DRIFT		1.000					4863.8294	-1.9163	-0.900	
8	QUAD	3Q84	7.000	-4.8100		-3506.97	55.37	4867.8294	-1.9199	-0.900	
9	DRIFT		30.000					4886.3294	-1.9366	-0.900	
10	QUAD	3Q84	7.000	4.6100		3361.15	50.86	4904.8294	-1.9532	-0.900	
11	DRIFT		1.000					4908.8294	-1.9568	-0.900	
12	QUAD	3Q84	7.000	4.6100		3361.15	50.86	4912.8294	-1.9604	-0.900	
13	DRIFT		1.000					4916.8295	-1.9640	-0.900	
14	QUAD	3Q84	7.000	4.6100		3361.15	50.86	4920.8295	-1.9676	-0.900	
15	DRIFT		1.500					4925.0795	-1.9715	-0.900	
16	DRIFT		10.000 3					4930.8294	-1.9766	-0.900	H COLLIMATOR
17	DRIFT		1.500					4936.5795	-1.9818	-0.900	
18	DRIFT		10.000	2'				4942.3294	-1.9870	-0.900	V COLLIMATOR
19	DRIFT		1.500 4					4948.0794	-1.9922	-0.900	
20	BEND	6-4-30	2.500	0.0000	0.000	0.00	0.00	4950.0794	-1.9940	-0.900	VERTICAL VERNIER
21	DRIFT		3.000					4952.8294	-1.9964	-0.900	
22	QUAD	3Q84	7.000	-4.8100		-3506.97	55.37	4957.8295	-2.0009	-0.900	
23	DRIFT		1.000					4961.8294	-2.0045	-0.900	
24	QUAD	3Q52	4.330	-4.8100		-3506.97	32.12	4964.4944	-2.0069	-0.900	
25	DRIFT		5.600					4969.4595	-2.0114	-0.900	
26	BEND	5-1.5-240	20.000	-15.0475	-5.500	-3895.80	89.91	4982.2595	-2.0229	-6.400	
27	DRIFT		23.440					5003.9791	-2.1619	-6.400	
28	DRIFT		0.000					5015.6988	-2.2369	-6.400	TARGET
29	DRIFT		1.000					5016.1988	-2.2401	-6.400	
30	BEND	5-1.5-120	10.000	0.0000	0.000	0.00	0.00	5021.6987	-2.2753	-6.400	TARGET MAGNET
31	DRIFT		1.000					5027.1986	-2.3105	-6.400	
32	DRIFT		0.000					5027.6986	-2.3137	-6.400	SWIC, PWC BOTH PLANE
33	DRIFT		0.000					5027.6986	-2.3137	-6.400	90 DEG SCINT MONITOR
34	DRIFT		0.000					5027.6986	-2.3137	-6.400	REMOVABLE SCINT
35	DRIFT		0.000					5027.6986	-2.3137	-6.400	HADRON BEAM TARGET

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TABLE 3 Beam N3 Instrumentation

Location	Device	Purpose
Enclosure 101		
Before first quadrupole	Vertical collimator	Determines vertical acceptance
After second quadrupole	Horizontal collimator	Determines horizontal acceptance
After last bending magnet	Vertical vernier	Steer beam vertically
Enclosure 103		
Just before F_{1H}	Correlated horizontal and vertical PWC	Determines beam profile
At F_{1H}	Horizontal collimator and plastic scintillator	Determines momentum bite
Just after F_{1H}	Bending magnet separating N3-N5 beams	Steer onto next horizontal collimator
Just before F_{1V}	Vertical PWC	Determine vertical profile
At F_{1V}	Vertical collimator	Redefine target image
Just after F_{1V}	Vertical vernier	Steer onto next enclosure
Enclosure 105		
After quadrupole of Enclosure 105	Horizontal and vertical vernier magnets	Steer onto next horizontal and vertical collimators
Between Enclosure 105 and 108	Threshold Cerenkov counters	Mass identification of particles
Enclosure 108		
Just before F_{2V}	Vertical PWC	Determine vertical profile
At F_{2V}	Vertical collimator	Redefine target image
Enclosure 110		
Just before F_{2H}	Horizontal PWC	Determine horizontal profile
At F_{2H}	Horizontal collimator	Redefine momentum bite

TABLE 3 Continued

Enclosure 114		
After last bending magnet	Horizontal and vertical proportional chambers	Determine particle angle and position at chamber to correlate with mass determination in Cerenkov counter.
Before bubble chamber	Horizontal and vertical proportional chambers	
At Enclosure 114 and just before bubble chamber	Scintillation counters	Provide fast coincidence signals

Closed Control Loops

1. Vertical vernier magnet of Enclosure 101 and vertical PWC of Enclosure 103.
2. Horizontal vernier of Enclosure 105 and horizontal PWC of Enclosure 110.
3. Vertical vernier of Enclosure 105 and vertical PWC of Enclosure 108.
4. Pitching magnet of Enclosure 112 and vertical PWC of Enclosure 114.
5. Bending magnet of Enclosure 112 and horizontal PWC of Enclosure 114.

MOMENTUM 500.00000
TARGET Z 5027.69992
X -2.31370
ANGLE -3.40000

BEAM N3 TO 30 INCH BUBBLE CHAMBER MARCH 29, 1971 FINAL

	ELEMENT		LENGTH	FIELD	BEND	CURRENT	POWER	Z	X	ANGLE	
1	DRIFT		0.000					5027.6999	-2.3137	-3.400	TARGET
2	DRIFT		1.000					5028.1999	-2.3154	-3.400	
3	BEND	5-1.5-120	10.000	0.0000	0.000	0.00	0.00	5033.6999	-2.3341	-3.400	TARGET MAGNET
4	DRIFT		270.600					5173.9991	-2.8111	-3.400	
5	DRIFT		10.000					5314.2984	-3.2881	-3.400	V COLLIMATOR
6	DRIFT		1.500					5320.0484	-3.3077	-3.400	SCINTILLATOR
7	QUAD	3Q84	7.000	-6.9150		-5041.73	114.44	5324.2984	-3.3221	-3.400	
8	DRIFT		1.500					5328.5483	-3.3366	-3.400	
9	BEND	4-2-240	20.000	-15.0475	-5.500	-3895.80	108.32	5339.2983	-3.3731	-8.900	
10	DRIFT		1.500					5350.0479	-3.4688	-8.900	
11	BEND	4-2-240	20.000	-15.0475	-5.500	-3895.80	108.32	5360.7975	-3.5645	-14.400	
12	DRIFT		1.500					5371.5465	-3.7193	-14.400	SCINTILLATOR
13	QUAD	3Q84	7.000	6.3660		4641.45	96.99	5375.7960	-3.7805	-14.400	
14	DRIFT		1.500					5380.0455	-3.8417	-14.400	T
15	DRIFT		10.000					5385.7949	-3.9245	-14.400	H COLLIMATOR
16	DRIFT		1.500					5391.5443	-4.0073	-14.400	
17	BEND	5-1.5-240	20.000	-15.0475	-5.500	-3895.80	89.91	5402.2933	-4.1621	-19.900	
18	DRIFT		1.500					5413.0412	-4.3760	-19.900	
19	BEND	5-1.5-240	20.000	-15.0475	-5.500	-3895.80	89.91	5423.7890	-4.5899	-25.400	
20	DRIFT		1.500					5434.5356	-4.8629	-25.400	
21	BEND	5-1.5-240	20.000	-15.0475	-5.500	-3895.80	89.91	5445.2822	-5.1359	-30.900	
22	DRIFT		1.500					5456.0271	-5.4681	-30.900	SCINTILLATOR
23	BEND	6-4-30	2.500	0.0000	0.000	0.00	0.00	5458.0261	-5.5298	-30.900	VERTICAL VERNIER
24	DRIFT		589.100					5753.6849	-14.6686	-30.900	
25	DRIFT		0.000					6048.0943	-23.7687	-30.900	SCINTILLATOR
26	DRIFT		0.000					6048.0943	-23.7687	-30.900	H AND V PWC
27	DRIFT		10.000					6053.0919	-23.9232	-30.900	HORIZONTAL SLIT
28	DRIFT		1.500					6058.8391	-24.1008	-30.900	
29	BEND	5-1.5-120	10.000	-8.2078	-1.500	-922.55	14.89	6064.5863	-24.2785	-32.400	N3-N5 SWITCH
30	DRIFT		1.500					6070.3334	-24.4647	-32.400	
31	BEND	5-1.5-120	10.000	-8.2078	-1.500	-922.55	14.89	6076.0803	-24.6510	-33.900	N3-N5 SWITCH
32	DRIFT		34.750					6098.4425	-25.4094	-33.900	
33	DRIFT		0.000					6115.8075	-25.9983	-33.900	SCINTILLATOR
34	DRIFT		0.000					6115.8075	-25.9983	-33.900	VERTICAL PWC
35	DRIFT		10.000					6120.8046	-26.1677	-33.900	VERTICAL SLIT
36	DRIFT		1.500					6126.5513	-26.3626	-33.900	
37	BEND	6-4-30	2.500	0.0000	0.000	0.00	0.00	6128.5502	-26.4374	-33.900	VERTICAL VERNIER
38	DRIFT		468.000					6363.6650	-34.4038	-33.900	
39	DRIFT		0.000					6597.5305	-42.3349	-33.900	SCINTILLATOR
40	QUAD	3Q84	7.000	5.7350		4181.39	78.71	6601.0284	-42.4535	-33.900	

ENCL 100
5052
5300
ENCL 101
5472
6043
ENCL 103
6132
6519
COMMON WITH N5

Table 4 Cont

' BEAM N3 TO 30 INCH BUBBLE CHAMBER MARCH 29, 1971 FINAL

		ELEMENT		LENGTH	FIELD	BEND	CURRENT	POWER	Z	X	ANGLE	
ENCL 105	41	DRIFT		37.000					6623.0159	-43.1992	-33.900	
	42	BEND	6-4-30	2.500	0.0000	0.000	0.00	0.00	6642.7545	-43.8686	-33.900	HORIZONTAL VERNIER
	43	DRIFT		1.500					6644.7534	-43.9363	-33.900	
	44	BEND	6-4-30	2.500	0.0000	0.000	0.00	0.00	6646.7522	-44.0041	-33.900	VERTICAL VERNIER
	45	DRIFT		1.500					6648.7510	-44.0719	-33.900	
	46	QUAD	3Q84	7.000	-5.8620		-4273.98	82.24	6652.9986	-44.2160	-33.900	
	47	DRIFT		1.500					6657.2461	-44.3600	-33.900	SCINTILLATOR
	48	BEND	UNDEFINED	3.000	0.0000	0.000	0.00	0.00	6659.4949	-44.4363	-33.900	FAST KICKER
6663	49	DRIFT		1.500					6661.7436	-44.5125	-33.900	
6768 ENCL 106	50	DRIFT		110.000					6717.4616	-46.4021	-33.900	CERENKOV COUNTER
6804	51	DRIFT		30.000					6787.4214	-48.7746	-33.900	
6912	52	DRIFT		115.000					6859.8798	-51.2319	-33.900	CERENKOV COUNTER
6924 ENCL 107	53	DRIFT		1.500					6918.0962	-53.2062	-33.900	SCINTILLATOR
7153	54	DRIFT		236.000					7036.7780	-57.2310	-33.900	
ENCL 108	55	QUAD	3Q120	10.000	3.0000		63.60	7.66	7159.7074	-61.3999	-33.900	
	56	DRIFT		1.500					7165.4540	-61.5948	-33.900	
	57	DRIFT		0.000					7166.2036	-61.6202	-33.900	SCINTILLATOR
	58	DRIFT		0.000					7166.2036	-61.6202	-33.900	VERTICAL PWC
7177	59	DRIFT		10.000					7171.2048	-61.7897	-33.900	VERTICAL SLIT
7223	60	DRIFT		48.000					7240.1841	-62.7726	-33.900	
ENCL 109	61	DRIFT		0.000					7224.1703	-63.5860	-33.900	SCINTILLATOR
	62	DRIFT		0.000					7224.1703	-63.5860	-33.900	HORIZONTAL PWC
7235	63	DRIFT		10.000					7229.1674	-63.7555	-33.900	HORIZONTAL SLIT
7509	64	DRIFT		277.000					7372.5849	-68.6192	-33.900	
ENCL 112	65	DRIFT		0.250					7511.1303	-73.3177	-33.900	
	66	BEND	5-1.5-120	10.000	9.3021	1.700	1045.56	19.13	7516.2524	-73.4914	-32.200	
	67	DRIFT		1.500					7521.9995	-73.6765	-32.200	
	68	BEND	5-1.5-120	10.000	9.3021	1.700	1045.56	19.13	7527.7464	-73.8616	-30.500	
	69	DRIFT		1.500					7533.4937	-74.0370	-30.500	
	70	BEND	5-1.5-120	10.000	9.3021	0.000	1045.56	19.13	7539.2412	-74.2123	-30.500	PITCHING MAGNET1.7MR
	71	DRIFT		1.500					7544.9885	-74.3877	-30.500	
	72	BEND	5-1.5-120	10.000	9.3021	0.000	1045.56	19.13	7550.7359	-74.5630	-30.500	PITCHING MAGNET1.7MR
	73	DRIFT		1.500					7556.4832	-74.7384	-30.500	
7569	74	QUAD	3Q120	10.000	-5.2000		-110.24	23.02	7562.2305	-74.9137	-30.500	
7673	75	DRIFT		108.100					7621.2531	-76.7144	-30.500	
ENCL 114	76	DRIFT		10.000					7680.2757	-78.5152	-30.500	VERTICAL SLIT
	77	DRIFT		1.500					7686.0230	-78.6905	-30.500	
	78	QUAD	4Q120	10.000	3.1000		301.78	36.61	7691.7703	-78.8659	-30.500	4Q120 SPECIAL
	79	DRIFT		1.500					7697.5176	-79.0412	-30.500	
	80	BEND	5-1.5-120	10.000	15.0476	2.750	1691.35	50.06	7703.2650	-79.2166	-27.750	
	81	DRIFT		1.500					7709.0129	-79.3761	-27.750	
	82	BEND	5-1.5-120	10.000	15.0476	2.750	1691.35	50.06	7714.7608	-79.5357	-25.000	
	83	DRIFT		0.000					7719.7591	-79.6606	-25.000	SCINTILLATOR
	84	DRIFT		0.000					7719.7591	-79.6606	-25.000	HORIZONTAL PWC
7721	85	DRIFT		0.000					7719.7591	-79.6606	-25.000	VERTICAL PWC
	86	DRIFT		554.400					7996.8724	-86.5899	-25.000	
	87	DRIFT		0.000					8273.9860	-93.5191	-25.000	SCINTILLATOR
	88	DRIFT		0.000					8273.9860	-93.5191	-25.000	HORIZONTAL PWC
	89	DRIFT		0.000					8273.9860	-93.5191	-25.000	VERTICAL PWC
	90	DRIFT		20.000					8283.9827	-93.7691	-25.000	
	91	DRIFT		0.000					8293.9798	-94.0191	-25.000	30 INCH HBC

TABLE 5 Beam N5 Instrumentation

Location	Device	Purpose
Enclosure 111		
Same as for Beam N3		
Enclosure 103		
Same as for Beam N3 up through bending magnet separating N3 and N5 beams		
Just before F_{1V}	Vertical PWC	Determine vertical profile and centroid.
At F_{1V}	Vertical collimator	Redefine target image and help clean-up spray from horizontal slit.
Just after F_{1V}	Vertical vernier	Steer onto next enclosure.
Enclosure 105		
Effective center at third bending magnet	All bending magnets in Enclosure 105	Steer onto next collimator.
Just after last quadrupole in Enclosure 105	Vertical vernier	Steer onto next vertical collimator.
Enclosure 106		
Between quadrupoles and F_{2H}	Horizontal PWC	Determine horizontal profile also used in momentum tagging.
At F_{2H}	Horizontal collimator	Clean up halo from first horizontal collimator and redetermine momentum bite.
Enclosure 107		
Just before F_{2V}	Vertical PWC	Determine vertical profile and centroid.
At F_{2V}	Vertical collimator	Redefine target image.

TABLE 5 Continued

Enclosure 109		
Effective center at fifth bending magnet	All bending magnets in Enclosure 109	Steer beam onto next collimator
After last quadrupole in Enclosure 109	Vertical vernier	Steer beam onto next vertical collimator.
Enclosure 111		
Just before F_{3H}	Horizontal and vertical PWC's	Determine horizontal and vertical profiles - can be used to check recombination.
At F_{3H}	Horizontal collimator	Clean up horizontal image.
At F_{3V}	Vertical collimator	Clean up vertical image.
Enclosure 113		
In parallel section of beam	DISC counter	Tag particle mass - can also be used to determine momentum and $\Delta p/p$ of beam.
Enclosure 115		
After last quadrupole	Horizontal vernier Vertical vernier	Steer beam into bubble chamber.
After vernier magnets	Horizontal and vertical PWC	Used to tag particle's direction into bubble chamber.
Lab B		
Upstream of bubble chamber	Horizontal and vertical PWC	Used to tag particle's direction and position into bubble chamber.

TABLE 5 Continued

Closed Control Loops

1. Vertical vernier dipole in Enclosure 101 and vertical PWC just before F_{1V} in Enclosure 103.
2. Horizontal vernier dipole in Enclosure 105 and horizontal PWC before F_{2H} in Enclosure 106.
3. Vertical vernier dipole in Enclosure 105 and vertical PWC before F_{2V} in Enclosure 107.
4. Horizontal vernier dipole in Enclosure 107 and horizontal PWC before F_{3H} in Enclosure 111.
5. Vertical vernier dipole in Enclosure 107 and vertical PWC before F_{3V} in Enclosure 111.
6. Horizontal vernier dipole in Enclosure 111 and horizontal PWC in Lab B before bubble chamber.
7. Vertical vernier dipole in Enclosure 111 and vertical PWC in Lab B before bubble chamber.

MAGNET COORDINATE CODE

MOMENTUM	500,00000
TARGET Z	5027,69992
X	-2,31370
ANGLE	-3,40000

'BEAM N5 WITH OFFICIAL SET OF MAGNETS VERNIERS AND INSTRUMENTATION MARCH 17, 71

			ELEMENT	LENGTH	FIELD	BEND	CURRENT	POWER	Z	X	ANGLE	
ENCL 100	1	DRIFT		0,000					5027,6999	-2,3137	-3,400	TARGET
	2	DRIFT		1,000					5028.1999	-2.3154	-3,400	
5052	3	BEND	5-1,5-120	10,000	0,0000	0,000	0,00	0.00	5033,6999	-2,3341	-3,400	TARGET MAGNET
5300	4	DRIFT		270,600					5173,9991	-2,8111	-3.400	
	5	DRIFT		10,000					5314,2984	-3,2881	-3,400	V COLLIMATOR
	6	DRIFT		1,500					5320,0484	-3,3077	-3,400	SCINTILLATOR
	7	QUAD	3Q84	7,000	-6,9100		-5038,08	114,27	5324,2984	-3,3221	-3,400	
	8	DRIFT		1,500					5328,5483	-3,3366	-3,400	
	9	BEND	4-2-240	20,000	-15,0475	-5,500	-3895,80	108,32	5339,2983	-3,3731	-8,900	
	10	DRIFT		1,500					5350,0479	-3,4688	-8,900	
	11	BEND	4-2-240	20,000	-15,0475	-5,500	-3895,80	108,32	5360,7975	-3,5645	-14,400	
ENCL 101	12	DRIFT		1,500					5371,5465	-3,7193	-14,400	SCINTILLATOR
	13	QUAD	3Q84	7,000	6.3640		4639.99	96.93	5375,7960	-3,7805	-14,400	
	14	DRIFT		1,500					5380,0455	-3,8417	-14,400	
	15	DRIFT		10,000					5385,7949	-3,9245	-14,400	H COLLIMATOR
	16	DRIFT		1,500					5391,5443	-4,0073	-14,400	
	17	BEND	5-1,5-240	20,000	-15,0475	-5,500	-3895,80	89,91	5402,2933	-4,1621	-19,900	
	18	DRIFT		1,500					5413,0412	-4,3760	-19,900	
	19	BEND	5-1,5-240	20,000	-15,0475	-5,500	-3895,80	89,91	5423,7890	-4,5899	-25,400	
	20	DRIFT		1,500					5434,5356	-4,8629	-25,400	
	21	BEND	5-1,5-240	20,000	-15,0475	-5,500	-3895,80	89,91	5445,2822	-5,1359	-30,900	
	22	DRIFT		1,500					5456,0271	-5,4681	-30,900	SCINTILLATOR
5412	23	BEND	6-4-30	2,500	0,0000	0,000	0,00	0,00	5458,0261	-5,5298	-30,900	VERTICAL VERNIER
6043	24	DRIFT		589,100					5753,6849	-14,6686	-30,900	
	25	DRIFT		0,000					6048,0943	-23,7687	-30,900	SCINT, H AND V PWC
	26	DRIFT		10,000					6053,0919	-23,9232	-30,900	HORIZONTAL SLIT
	27	DRIFT		1,500					6058,8391	-24,1008	-30,900	
	28	BEND	5-1,5-120	10,000	0,0000	0,000	0,00	0,00	6064,5863	-24,2785	-30,900	N3-N5 SWITCH
	29	DRIFT		1,500					6070,3336	-24,4561	-30,900	
ENCL 103	30	BEND	5-1,5-120	10,000	0,0000	0,000	0,00	0,00	6076,0809	-24,6337	-30,900	N3-N5 SWITCH
	31	DRIFT		34,750					6098,4452	-25,3250	-30,900	
	32	DRIFT		0,000					6115,8119	-25,8618	-30,900	SCINT AND V PWC
	33	DRIFT		10,000					6120,8095	-26,0163	-30,900	VERTICAL SLIT
	34	DRIFT		1,500					6126,5568	-26,1939	-30,900	
6132	35	BEND	6-4-30	2,500	0,0000	0,000	0,00	0,00	6128,5558	-26,2557	-30,900	VERTICAL VERNIER
6519	36	DRIFT		396,000					6327,7106	-32,4116	-30,900	
	37	DRIFT		0,000					6525,6162	-38,5288	-30,900	SCINTILLATOR
	38	BEND	5-1,5-240	20,000	15,0475	5,500	3895,80	89,91	6535,6114	-38,8377	-25,400	
	39	DRIFT		1,500					6546,3579	-39,1107	-25,400	
	40	BEND	5-1,5-240	20,000	15,0475	5,500	3895,80	89,91	6557,1046	-39,3838	-19,900	

COMMON ELEMENTS WITH BEAM N3

2254.000

Table 6 Cont

'BEAM N5 WITH OFFICIAL SET OF MAGNETS VERNIERS AND INSTRUMENTATION MARCH 17, 71'

			ELEMENT	LENGTH	FIELD	BEND	CURRENT	POWER	Z	X	ANGLE	
	41	DRIFT		1,500					6567.8525	-39.5977	-19.900	T
	42	QUAD	3Q84	7.000	6.4750		4720.92	100.34	6572.1016	-39.6822	-19.900	
	43	DRIFT		1.500					6576.3509	-39.7668	-19.900	
ENCL 105	44	BEND	5-1.5-240	20.000	15.0475	5.500	3895.80	89.91	6587.0986	-39.9807	-14.400	
	45	DRIFT		1.500					6597.8476	-40.1355	-14.400	
	46	BEND	5-1.5-240	20.000	15.0475	5.500	3895.80	89.91	6608.5965	-40.2903	-8.900	
	47	DRIFT		1.500					6619.3461	-40.3860	-8.900	
	48	BEND	4-2-240	20.000	15.0475	5.500	3895.80	108.32	6630.0957	-40.4817	-3.400	
	49	DRIFT		1.500					6640.8458	-40.5182	-3.400	
	50	QUAD	3Q52	4.330	-6.4640		-4712.90	58.02	6643.7607	-40.5281	-3.400	
	51	DRIFT		1.500					6646.6756	-40.5380	-3.400	
	52	QUAD	3Q52	4.330	-6.4640		-4712.90	58.02	6649.5907	-40.5479	-3.400	
	53	DRIFT		1.500					6652.5056	-40.5579	-3.400	
	54	BEND	UNDEFINED	3.000	0.0020	0.000	0.00	0.00	6654.7556	-40.5655	-3.400	VERTICAL KICKER
	55	DRIFT		1.500					6657.0056	-40.5731	-3.400	
6662	56	BEND	6-4-30	2.500	0.0070	0.000	0.00	0.00	6659.0056	-40.5799	-3.400	VERTICAL VERNIER
6768	57	DRIFT		110.100					6715.3053	-40.7714	-3.400	
	58	QUAD	3Q120	10.000	3.2830		69.60	9.17	6775.3550	-40.9755	-3.400	
	59	DRIFT		1.500					6781.1049	-40.9951	-3.400	
ENCL 106	60	QUAD	3Q120	10.000	3.2830		69.60	9.17	6786.8549	-41.0146	-3.400	
	61	DRIFT		0.000					6791.8549	-41.0316	-3.400	SCINT AND H PWC
	62	DRIFT		1.500					6792.6049	-41.0342	-3.400	
6804	63	DRIFT		10.000					6798.3548	-41.0537	-3.400	HORIZONTAL SLIT
6912	64	DRIFT		110.000					6858.3545	-41.2577	-3.400	
ENCL 107	65	DRIFT		0.000					6913.3542	-41.4447	-3.400	SCINT AND V PWC
6924	66	DRIFT		10.000					6918.3542	-41.4617	-3.400	VERTICAL SLIT
7063	67	DRIFT		147.700					6997.2037	-41.7298	-3.400	
	68	BEND	5-1.5-240	20.000	15.0475	5.500	3895.80	89.91	7081.0533	-42.0149	2.100	
	69	DRIFT		1.500					7091.8033	-41.9923	2.100	
	70	BEND	5-1.5-240	20.000	15.0475	5.500	3895.80	89.91	7102.5533	-41.9698	7.600	
	71	DRIFT		1.500					7113.3030	-41.8881	7.600	
	72	BEND	5-1.5-240	20.000	15.0475	5.500	3895.80	89.91	7124.0527	-41.8064	13.100	
	73	DRIFT		1.500					7134.8019	-41.6655	13.100	
	74	BEND	5-1.5-240	20.000	15.0475	5.500	3895.80	89.91	7145.5511	-41.5247	18.600	
	75	DRIFT		1.500					7156.2993	-41.3248	18.600	
	76	BEND	5-1.5-240	20.000	15.0475	5.500	3895.80	89.91	7167.0473	-41.1248	24.100	
	77	DRIFT		1.500					7177.7943	-40.8658	24.100	
	78	BEND	5-1.5-240	20.000	15.0475	5.500	3895.80	89.91	7188.5411	-40.6068	29.600	
	79	DRIFT		1.500					7199.2866	-40.2886	29.600	T
	80	QUAD	3Q84	7.000	6.6480		4847.06	105.77	7203.5346	-40.1628	29.600	
	81	DRIFT		1.500					7207.7829	-40.0370	29.600	
ENCL 109	82	BEND	5-1.5-240	20.000	15.0475	5.500	3895.80	89.91	7218.5281	-39.7189	35.100	
	83	DRIFT		1.500					7229.2715	-39.3416	35.100	
	84	BEND	4-2-240	20.000	15.0475	5.500	3895.80	108.32	7240.0150	-38.9644	40.600	
	85	DRIFT		1.500					7250.7562	-38.5281	40.600	
	86	BEND	4-2-240	20.000	15.0475	5.500	3895.80	108.32	7261.4975	-38.0917	46.100	
	87	DRIFT		1.500					7272.2360	-37.5963	46.100	
	88	QUAD	3Q52	4.330	-6.4020		-4667.70	56.91	7275.1480	-37.4620	46.100	
	89	DRIFT		1.500					7278.0599	-37.3277	46.100	
	90	QUAD	3Q52	4.330	-6.4020		-4667.70	56.91	7280.9719	-37.1933	46.100	

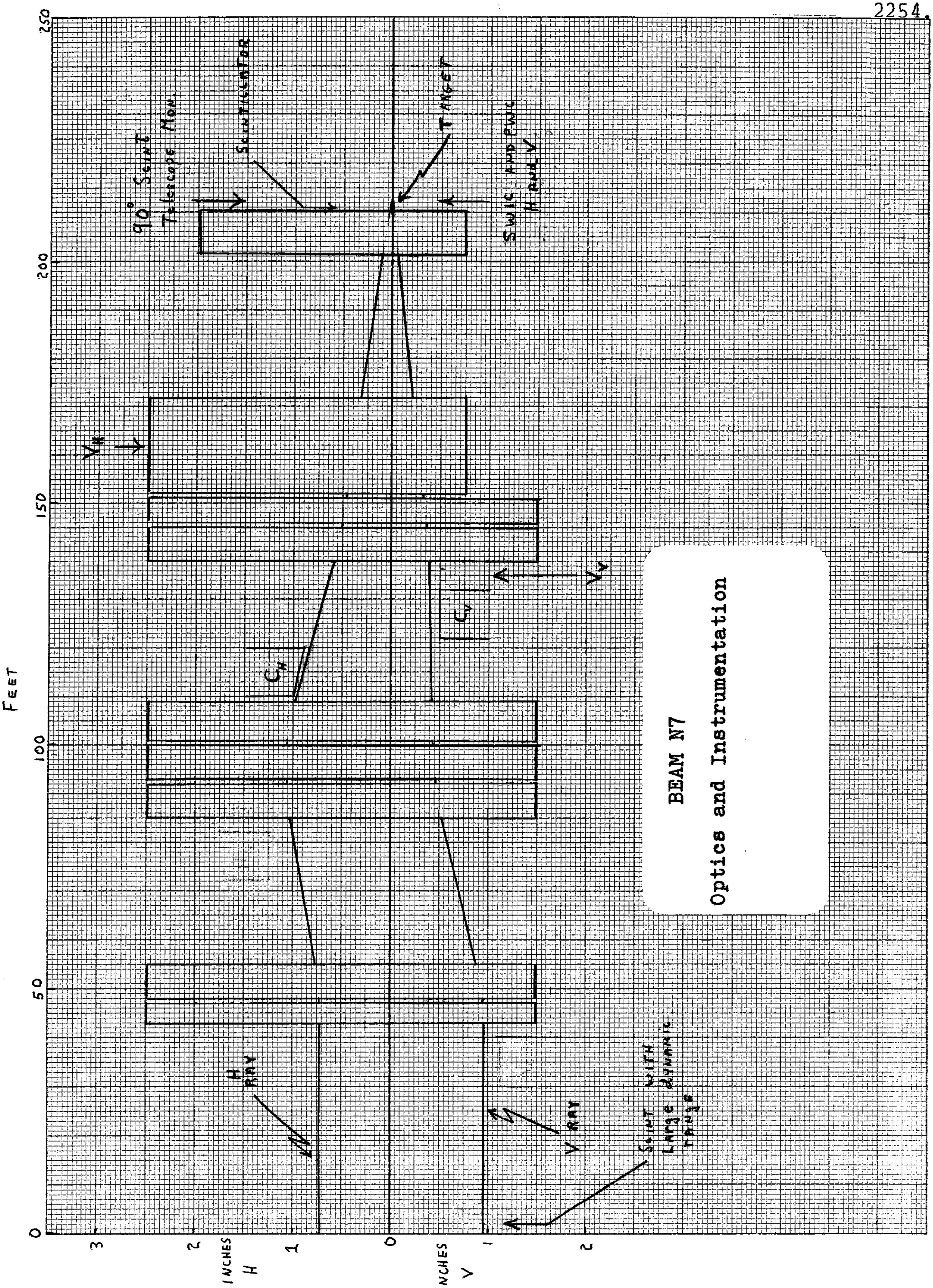
TM-298

2254.000

Table 6 Cont

'BEAM N5 WITH OFFICIAL SET OF MAGNETS VERNIERS AND INSTRUMENTATION MARCH 17, 71'

		ELEMENT		LENGTH	FIELD	BEND	CURRENT	POWER	Z	X	ANGLE	
	91	DRIFT		1,500					7283.8837	-37.0590	46.100	
7251	92	BEND	6-4-30	2,500	0.0000	0.000	0.00	0.00	7285.8816	-36.9668	46.100	VERTICAL VERNIER
7455	93	DRIFT		176,000					7375.0367	-32.8539	46.100	
	94	DRIFT		0.000					7462.9432	-28.7985	46.100	SCINT AND H PWC
ENCL 111	95	DRIFT		10.000					7467.9379	-28.5631	46.100	HORIZONTAL SLIT
	96	DRIFT		'1.500					7473.6818	-28.3031	46.100	
	97	DRIFT		0,000					7474.4310	-28.2686	46.100	SCINT AND V PWC
7491	98	DRIFT		10.000					7479.4257	-28.0382	46.100	VERTICAL SLIT
7686	99	DRIFT		211,500					7590.0580	-22.9344	46.100	
	100	QUAD	3Q52	4.330	-5.2400		-3820.48	38.13	7697.8584	-17.9613	46.100	
	101	DRIFT		1,500					7700.7702	-17.8270	46.100	
	102	QUAD	3Q52	4,330	-5.2400		-3820.48	38.13	7703.6822	-17.6926	46.100	
	103	DRIFT		50.000					7730.8182	-16.4408	46.100	
	104	QUAD	3Q84	7.000	5.1200		3732.99	62.74	7759.2880	-15.1274	46.100	
	105	DRIFT		50,000					7787,7577	-13.8140	46.100	DISC FITS IN HERE
	106	QUAD	3Q52	4,330	6.8000		4957,88	64.20	7814.8939	-12.5622	46.100	
	107	DRIFT		1,500					7817.8057	-12.4278	46.100	
ENCL 113	108	QUAD	3Q52	4.330	6,8000		4957,88	64,20	7820.7177	-12.2935	46.100	
	109	DRIFT		1,500					7823.6295	-12,1592	46.100	
	110	QUAD	3Q84	7,000	6.8000		4957.88	110.66	7827.8750	-11,9633	46.100	
	111	DRIFT		1.500					7832.1224	-11.7675	46.100	
	112	BEND	6-4-30	2.500	0,0000	0.000	0.00	0.00	7834.1184	-11.6753	46.100	VERTICAL VERNIER
	113	DRIFT		1.500					7836.1163	-11.5831	46.100	
7841	114	BEND	6-4-30	2,500	0.0000	0.000	0,00	0.00	7838.1141	-11.4910	46.100	HORIZONTAL VERNIER
7877	115	DRIFT		40,000					7859.3415	-10.5117	46.100	
	116	QUAD	4Q120	10,000	-3.8000		-369,93	55.01	7884.3150	-9.3596	46.100	
ENCL 115	117	DRIFT		1.500					7890.0588	-9.0946	46.100	
	118	QUAD	4Q120	10.000	-3,8000		-369,93	55.01	7895.8027	-8,8296	46.100	
7901	119	DRIFT		0,000					7900.7974	-8,5992	46.100	SCINT, H AND V PWC
	120	DRIFT		151.400					7976.4170	-5.1107	46.100	
	121	DRIFT		0.000					8052.0366	-1,6222	46.100	SCINT, H AND V PWC
	122	DRIFT		20,000					8062.0260	-1.1613	46,100	
	123	DRIFT		0,000					8072.0153	-0.7005	46.100	15 FT BUBBLE CHAMBER



BEAM N7

Optics and Instrumentation

Figure 2

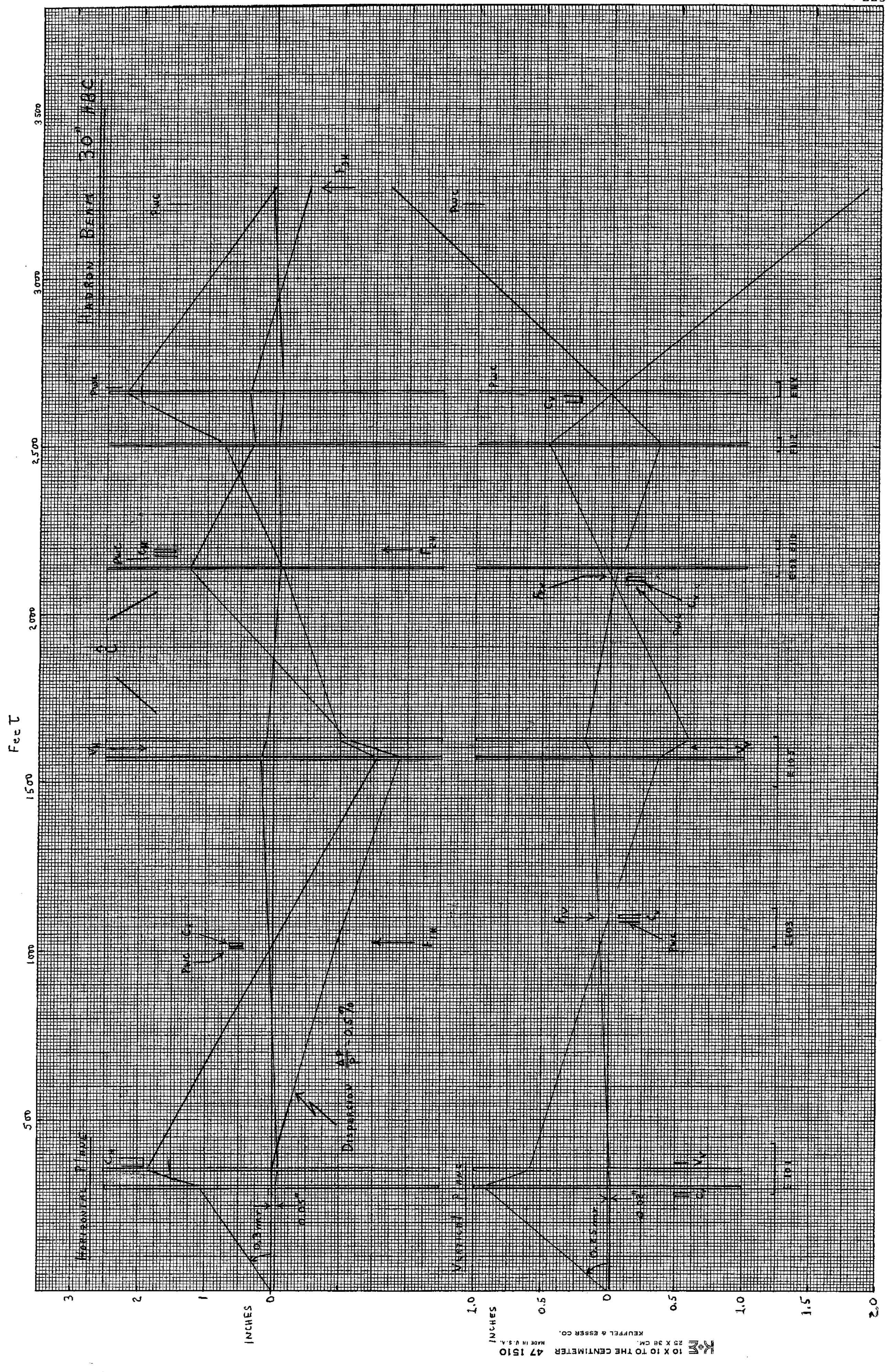
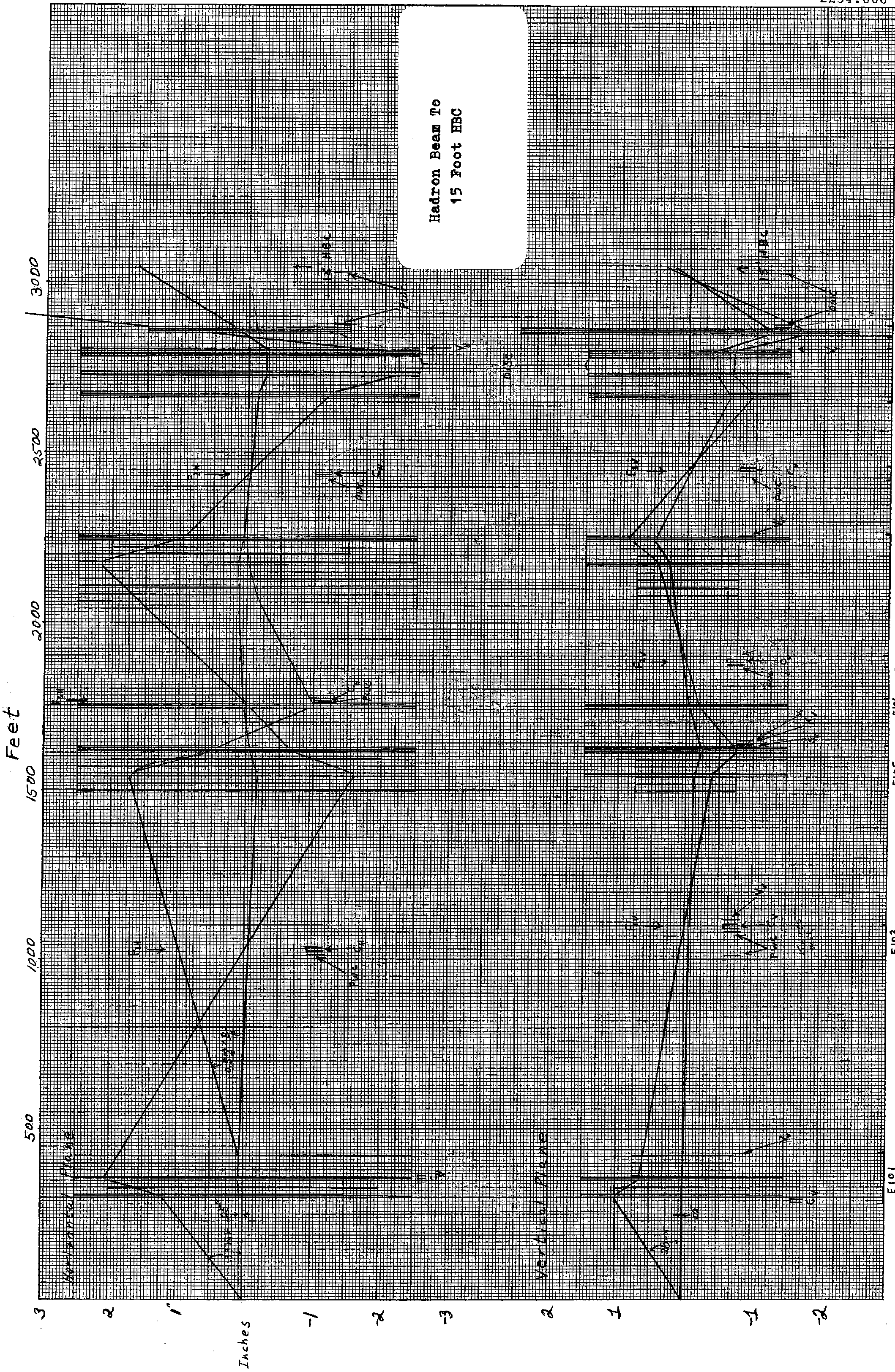

Hadron Beam 30" HBC
Feet
Inches
Horizontal Plane
Vertical Plane
Dispersion Δp/p = 0.5%

Figure 3


Hadron Beam To
15 Foot HBC
Horizontal Plane
Vertical Plane
Feet
Inches
500
1000
1500
2000
2500
3000
E101
E103
E105
E106
E107
E109
E111
E113
E115
15' HBC
PWC
DISC

APPENDIX A

DIFFERENTIAL - THRESHOLD CERENKOV COUNTERS

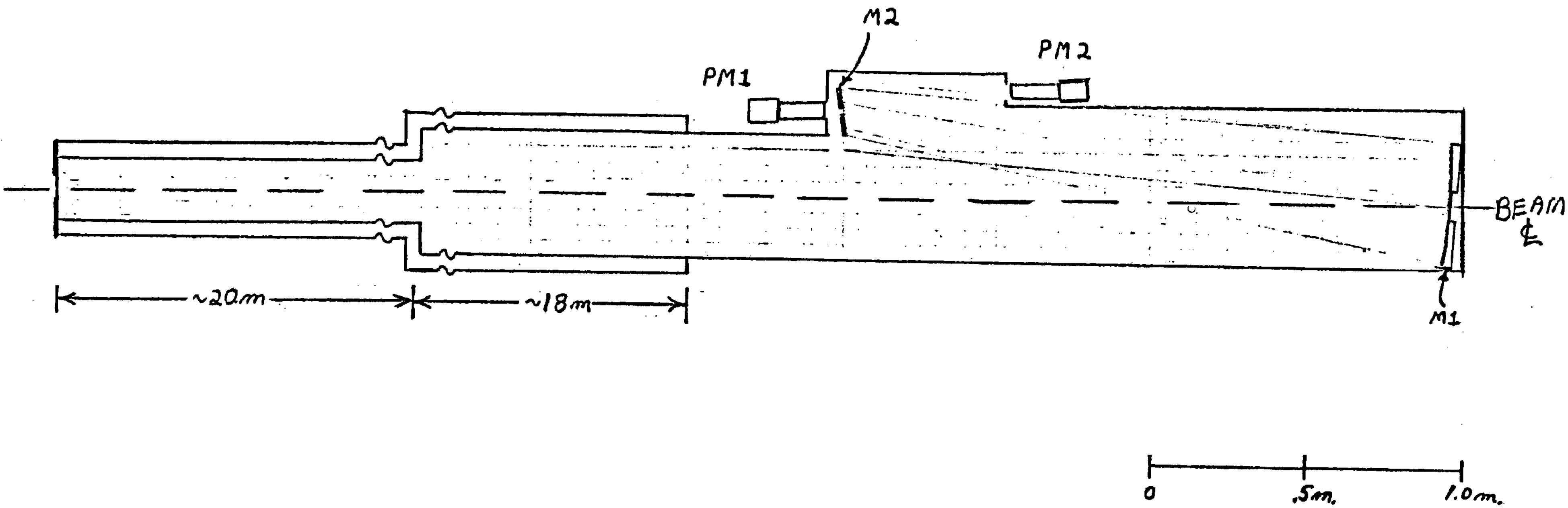
The present design of the Cerenkov counters for the hadron beam to the 30" bubble chamber is shown in Fig. 1. The total length of radiator (~ 80 m) will be divided between two nearly equal counters for two reasons. First, the members of the fifteen foot bubble chamber workshop recommended that this be done to reduce the probability of misidentifying protons because of delta rays. Second, since the highest resolution and efficiency is obtained for a counter without reflecting walls, the diameter of the focusing mirror M1 and the vessel near it are proportional to the length of the counter. By dividing the total length of radiator in two counters the volume of glass in a focusing mirror is reduced by a factor of 8 so that the two smaller mirrors should together be considerably less expensive than one larger mirror.

These counters can be operated as threshold counters by removing the diaphram mirror M2. In this mode the two counters could determine the kaon faction of 200 GeV/c charged beam to $\pm$ .5% (e.g. .014 $\pm$ .005).

By adding a second focusing mirror M2 with a small hole in its center the threshold counter can be converted to a simple differential counter. Because of its great length the counter achieves high efficiency at fairly small

Cerenkov angles (e.g. the efficiency of one 40 m counter at a Cerenkov angle of 2.5 mr is greater than 97%). One can thus operate with a kaon Cerenkov angle of 2.5 mr, which will lead to a pion angle of 2.9 mr at 300 GeV/c. For this beam and this counter the uncertainty in the direction of the Cerenkov light is dominated by the beam divergence (~ $\pm$ .16 mr for full solid angle and $\pm$ .1% $\Delta p/p$. The effect of dispersion for 300 GeV/c kaons with a Cerenkov angle of 2.5 mr is an uncertainty in the angle of .036 mr.). Thus if the hole in M2 is 1 cm in diameter, the light from kaons is detected in PM1 with a probability of 97%. Cerenkov light from pions is reflected by M2 so that they are not detected by PM1 but are detected by PM2, which can be used in veto. Thus up to ~ 300 GeV/c one of these counters can be reliably used to tag pions and kaons, leaving the other free to positively tag protons.

For beam momenta greater than 300 GeV/c, use of both counters with 5 mm diameter holes in the M2 mirrors will allow positive simultaneous identification of pions and kaons or of mesons and protons.



HADRON BEAM DIFFERENTIAL-THRESHOLD
CERENKOV COUNTER